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Nutritional and Antioxidant Characterization of Blanched Leafy Vegetables Consumed in Southern Côte d'Ivoire (Ivory Coast)

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Authors' contributions

This work was carried out in collaboration between all authors. Author FCA, managed the literature searches, wrote the protocol and wrote the first draft of the manuscript. Authors LTZ and SLN designed the study, managed the analyses and performed the statistical analysis of the study. All authors read and approved the final manuscript.

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ABSTRACT

The effect of blanching on the proximate composition, nutritive value and antioxidant properties of five leafy vegetable species (*Basella alba*, *Colocasia esculenta*, *Corchorus olitorius*, *Solanum melongena* and *Talinum triangulare*) used in the preparation of Ivorian diets was investigated. These leafy vegetables were subjected to steam blanching in a pressure cooker for 15, 25 and 45 min. This study highlighted losses ($P < 0.05$) of nutrients and anti-nutrients components at 15 min of blanching as follow: ash (6.68 – 33.80 %), proteins (0.56 - 15.71 %), vitamin C (4.75 – 73.21 %), carotenoids (18.77 - 72.76%) oxalates (2.16 – 42.62 %) and phytates (20.32 – 71.56 %). Contrary to the registered losses, the average increases of polyphenols and crude fibres contents at 15 min of blanching were 1.51 to 5.19% and 0.62 to 8.87%, respectively. Furthermore after 15 min of blanching time, the residual contents ($P < 0.05$) of minerals were: calcium (214.71 – 608.95 mg/100 g), magnesium (85.50 – 435 mg/100 g), potassium (1243.32 – 2940.38 mg/100 g), iron (17.07 – 45.86 mg/100 g) and zinc (17.48 – 64.03 mg/100 g). All the results above showed that blanching

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processing reduces nutritive value of leafy vegetables consumed in Southern Côte d'Ivoire. In order to contribute efficiently to the nutritional requirement and to the food security of Ivorian population, the domestic blanching time must be less than 15 min for preserving the beneficial nutritive properties of the studied leafy vegetables.

Keywords: Antioxidant properties; blanching processing; leafy vegetables; nutritive value.

1. INTRODUCTION

Leafy vegetables are plant species which leafy parts (young, succulent stems, flowers and very young fruit) are used as vegetable [1]. Traditional leafy vegetables have several agronomic advantages such as short growing period as they can be harvested within 3-4 weeks, they can also tolerate abiotic and biotic stress and they respond well to organic fertilizers [2]. Socio-economic surveys conducted in various parts of Africa indicate that African leafy vegetables (ALVs) are important commodities in household food and nutrition security [3]. The consumption of green leafy vegetables could improve the nutritional status of poor rural and urban households because these plants are rich sources of minerals, vitamins and antioxidant compounds such as carotenoids and phenolic agents [4,5]. Phenolic compounds are of nutritional interest with regard to their ability to quench free radicals in human body, reducing therefore neurodegenerative diseases [6]. The contents of these antioxidant compounds are mostly affected by factors such as temperature, light, oxygen and endogenous enzymes [7]. Increasing consumption of African indigenous vegetables may enhance crop diversity, alleviate poverty and promote food security [8]. Fresh leaves of most ALVs like amaranth (*Amaranthus*), slenderleaf (*Crotalaria brevidens*), spiderplant (*Chlorophytum comosum*), cowpea (*Vigna unguiculata*), pumpkin (cucurbits) and jute mallow (*Corchorus olitorius*) contain more than 100% of the recommended daily allowances for vitamins and minerals and 40% proteins for growing children and lactating mothers [9]. In spite of the beneficial nutrients indicated above, anti-nutrients such as tannins, phytates and oxalates have also been reported in leafy vegetables. Anti-nutritional factors are bioactive components which have the ability to form chelates with di-valent metallic ions such as Ca, Mg, Zn and Fe, thus decreasing their bioavailability in foods [10].

The perish ability of fresh leafy vegetables harvested in Africa is linked to their high moisture content and this fact decreases their nutritive value and limits also their utilization during seasons of the year. Therefore, to avoid post-harvest losses of leafy vegetables, it would be necessary to preserve their beneficial nutritive properties by using appropriate processing techniques for further safe storage [11]. One common processing using before consumption of leafy vegetables is blanching which is a mild heat treatment frequently applied to plants tissues prior to freezing, drying or canning in order to inactivate enzymes of deterioration [12]. Blanching may also remove tissues gases, shrink the product, clean and stabilize colour [13]. Usually carried out in hot water or in steam, this technique is used by indigenous people to reduce or eliminate the bitterness and anti-nutritional factors of the vegetables that are common in leaves [10]. Blanching affords also a series of secondary benefits, due to its washing action, such as elimination of off-flavors that may have been formed during the time between harvesting and processing, and removal of any residual pesticides [14]. Blanching, however, has some adverse effects, such as pigment modifications and nutrient losses [15,16].

Among the twenty hundred and seven (207) leafy vegetables widely consumed in tropical Africa, an average of twenty (20) leafy vegetables species are cultivated and used for consumption in Côte d'Ivoire (Ivory Coast) [17,18]. In addition, ethno-botanical surveys indicated the regional and cultural distribution area of these leafy vegetables and population in Southern Côte d'Ivoire (Ivory Coast) consume the following species: *Basella alba* "epinard", *Colocasia esculenta* "taro", *Corchorus olitorius* "kplala", *Solanum melongena* "aubergine" and *Talinum triangulare* "mamichou" [18,19]. Indeed, dietary habits of these populations include culinary preparation of these leafy vegetables as follow: the mature and freshly leaves are boiled in water for about 30 min in order to reduce bitter taste and then used, after discarding boiled water, for sauce preparation that accompany starchy cassava paste food commonly named "placali". Previous studies have highlighted the beneficial nutritive properties of the five leafy vegetables indicated above [20] but to the best of our knowledge, there is no sufficient reports regarding the blanching processing effect on the physicochemical and nutritive characteristics of these leafy vegetables. So, the aim of this study is to discuss the impact of blanching processing on the nutritive potential of the selected leafy vegetables in order to explore their uses in diet and contribute therefore to the food security of population of Côte d'Ivoire (Ivory Coast).

2. MATERIALS AND METHODS

2.1 Samples Collection and Processing

The selected leafy vegetables: *Basella alba* "epinard", *Colocasia esculenta* "taro", *Corchorus olitorius* "kplala", *Solanum melongena* "aubergine" and *Talinum triangulare* "mamichou" were collected fresh from cultivated peri-urban farmlands of Abidjan (Côte d'Ivoire). The preliminary treatment of these leafy vegetables was conducted as described in previous own works [21,22]. Afterwards, the fresh leafy vegetables (250 g) were rinsed with deionised water and steam blanched for 15, 25 and 45 min in a pressure cooker. The blanched leafy vegetable species were drained at ambient temperature (25°C) and subjected to physicochemical analysis.

2.2 Chemicals

The chemicals used in the present work were of analytical grade. The solvents used (n-hexane, petroleum ether, acetone, ethanol and methanol) were purchased from Merck (Germany) and reagents (gallic acid, β-carotene, metaphosphoric acid, Folin-Ciocalteu, DPPH) from Sigma-Aldrich (USA).

2.3 Nutritive Properties

2.3.1 Proximate analysis

The recommended methods of the Association of Official Analytical Chemists [23] were used for the determination of proximate composition. The moisture content was determined by drying the sample (10 g) in an oven (Memmert, Germany) at 105°C until constant weight. Ash fraction was determined by incineration of dried sample (5 g) in a muffle furnace (Pyrolabo, France) at 550°C for 12 h while crude fibres content was estimated by weighting insoluble residue obtained after acid (H_2SO4, 0.25 M) and alkaline (NaOH, 0.3 M) digestion. Crude protein was estimated by the Kjeldahl method. Total protein was calculated by multiplying the evaluated nitrogen by 6.25. Fat was determined by hexane extraction in a Soxhlet apparatus. Total carbohydrates and calorific value were estimated on dry matter basis by using formulas described by Food and Agriculture Organization [24].

2.3.2 Mineral analysis

For the mineral composition, the ICP-MS (inductively coupled argon plasma mass spectrometer) method [25] was performed. A quantity (0.25 g) of ashes obtained from leafy vegetable species was homogenized with 10 mL of hydrochloric-nitric acid (1:1, v/v) mixture. The qualitative and quantitative composition of minerals was determined by using an argon plasma mass spectrometer (Agilent 7500c, USA). External standards of each mineral were used for calibration.

2.4 Anti-nutritional and Antioxidant Properties

Anti-nutritional factors (oxalates, phytates) and antioxidant parameters (vitamin C, carotenoids, polyphenols, antioxidant activity) determined in this study were performed by using analytical methods [26-31] described in previous own works [21,22].

2.5 Statistical analysis

All the experiments were conducted in triplicate and statistical analysis was performed using STATISTICA 7.1 software (StatSoft, France). The data obtained (mean ± standard deviation) were subjected to Duncan's test to evaluate differences between means at $P < 0.05$ level.

3. RESULTS AND DISCUSSION

3.1 Proximate Composition

The physicochemical parameters (ash, fibres, proteins, lipids, carbohydrates and calorific value) examined in this study is presented in Table 1. These parameters showed significant difference ($P < 0.05$) by comparison of species and blanching times. After 15 min of blanching, the ash content ranged from 7.96 ± 0.04 % (*C. olitorius*) to 20.07 ± 0.06 % (*T. triangulare*) with a decrease rate at 15 min ranged from 6.68 – 33.80 %. In spite of the ashes losses levels, the studied leafy vegetables may be considered as good sources of minerals when compared to values obtained for cereals and tubers [32]. As concern proteins content, blanching processing caused 0.56 to 15.71 % reduction after 15 min. This reduced protein contents could be attributed to the severity of thermal process during blanching which leads to protein degradation [33]. The proteins contents losses are lower than that (9.78 – 28%) reported for 15 min cooked Nigerian leafy vegetables [34]. This fact could be explained by the agronomic cultural conditions and the period of leafy vegetables harvesting. With regards to their protein contents (14.48 ± 0.00 and 21.00 ± 0.02 %) at 15 min, blanched leaves of *T. triangulare* and *C. olitorius* could be considered as non negligible sources in view to the minimal value (12%) recommended for protein foods [35]. Blanching of all selected leafy vegetables resulted in a slight increase (0.62 – 8.87 %) in their crude fibres content at 15 min. Indeed, the increase of temperature during blanching leads to the hydrolysis of glyosidic linkages of polysaccharides which could make the dietary fibres soluble [36]. Regarding the fibres contents at 15 min (12.51 – 24.15 %), appropriate intake of the studied blanched leafy vegetables may prevent from diabetes, colon cancer and constipation [37]. The relatively low values of lipids contents in the blanched leafy vegetables at 15 min of blanching (3.81 – 9.80 %) corroborates the fact that leafy vegetables constitute poor sources of lipids [38]. Furthermore, the calculated calorific values (241.29 – 279.12 kcal/100 g) may explain the general observation that vegetables are lower calorific foods due to their crude fat and moisture contents [39].

3.2 Mineral Composition

Mineral composition of blanched leafy vegetables used in this study is shown in Table 2. The residual contents of minerals after 15 min of blanching were significantly different ($P < 0.05$): calcium (214.71 – 608.95 mg/100g), magnesium (85.50 – 435 mg/100g), potassium (1243.32 – 2940.38 mg/100g), iron (17.07 – 45.86 mg/100g) and zinc (17.48 – 64.03 mg/100g). With regards to these values, the consumption of 15 min blanched leafy vegetables could be beneficial for the mineral requirements of human body. Indeed, the standard requirements indicated by the Food and Agriculture Organization for calcium, magnesium, iron and zinc are 1000, 400, 8 and 6 mg/day, respectively [40]. Calcium plays important role in growth and maintenance of bones while magnesium prevents diseases such as growth retardation, muscle degeneration and bleeding disorders [41,42]. Iron is known in prevention of anemia while zinc is used as important cofactor in vitamin A and vitamin E metabolisms [40,43]. The calculated [phytates]/[Ca] and [oxalate]/[Ca] ratios were analyzed (Table 3) in order to predict calcium bioavailability. These ratio values were below the limit value of 2.5 indicated to impair the bioavailability of calcium [44,45].

3.3 Anti-nutritional Factors

The effect of blanching on anti-nutritional factors (oxalates and phytates) contents is depicted in Fig. 1. Levels losses ($P < 0.05$) at 15 min were 2.16 – 42.62 % and 20.32– 71.56 % for oxalates and phytates, respectively. These percentage losses are similar to those (7 – 56%) of phytates obtained for blanched leafy vegetables from Thailand [46]. The reductions in oxalates and phytates contents during blanching could improve the health status of Ivorian consumers because oxalates and phytates reduce the bioavailability of calcium, magnesium, zinc and iron by chelating action [47]. Consequently, blanching processing appears as detoxification technique of leafy vegetables by removing anti-nutritional factors [48].

3.4 Antioxidant Properties

Blanching also resulted in a decrease of carotenoids and vitamin C contents as presented by Fig. 2. The estimated losses at 15 min of blanching varied from 18.77 to 72.76% for carotenoids. This observed decrease may be due to the isomerization and oxidation of β-carotene which is considered as source of provitamin A in plants [49,50]. Therefore, the studied leafy vegetables must be consumed with fat added in order to contribute positively to the vitamin A status of children [51]. As regards vitamin C content, blanching processing at 15 min caused a significant reduction ranged from 4.75 to 73.21 % (Fig. 2). This decrease in vitamin C is lower than that (60 – 90%) reported for blanched Indian leafy vegetables [52] but agrees with earlier findings on some Nigerian vegetables that reported 47.5 - 82.4% loss in vitamin C content during blanching [16]. It is important to highlight that ascorbic acid (vitamin C) is a water-soluble and heat sensitive antioxidant component that facilitates iron absorption in human body [53]. In order to cover the daily need (40 mg) for vitamin C [40], the studied blanched leafy vegetables may be supplemented with other foods such as tropical fruits used as valuable sources of vitamin C. The Fig. 3 shows the effect of blanching on polyphenols content and antioxidant activity of the selected leafy vegetables. It was observed a slight increase of polyphenols contents varying from 1.51 to 5.19%. The percent gain in the total phenol content during cooking may be due to the breakdown of cell walls and release of phenolic compounds trapped in the fibres of green leafy vegetables [54]. This result agrees with earlier reports where ferulic acid, a phenolic component found in the cell wall of grains such as corn, wheat and oats, doubled after 10 min of cooking [55]. The contents in polyphenols which is linked to the antioxidant activity of the studied blanched leafy vegetables could be advantageous for lower cellular oxidative stress, which has been implicated in the pathogenesis of various neurodegenerative diseases, including Alzheimer's disease, Parkinson's disease, and amyotrophic lateral sclerosis [56,57].

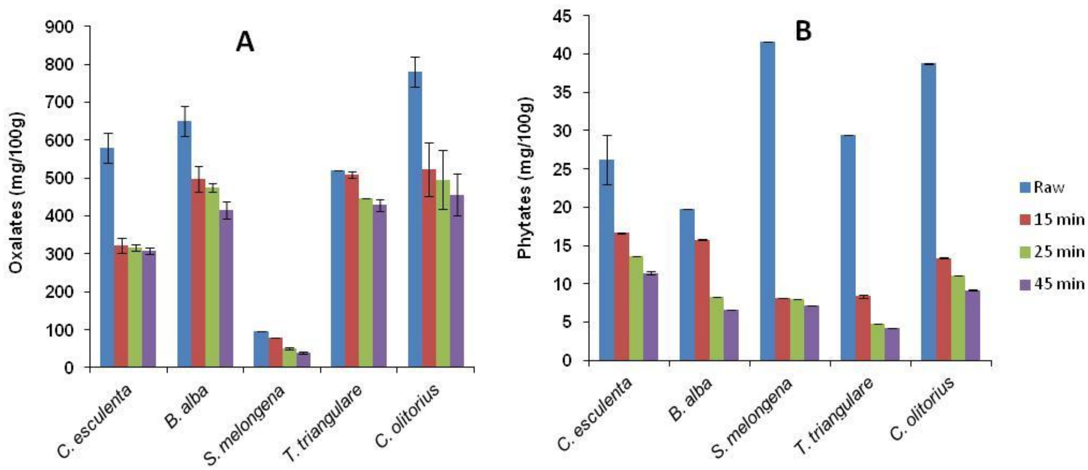

Fig. 1. Oxalates (A) and phytates (B) contents of raw and blanched leafy vegetables consumed in Southern Côte d'Ivoire

Mean ± S.E.M = Mean values ± Standard error of means of triplicate

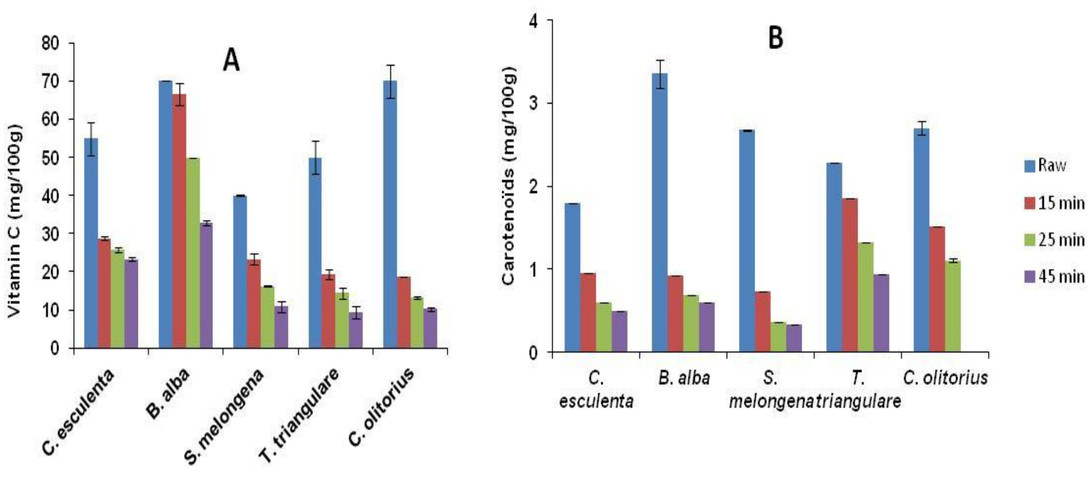

Fig. 2. Vitamin C (A) and carotenoids (B) contents of raw and blanched leafy vegetables consumed in Southern Côte d'Ivoire

Mean ± S.E.M = Mean values ± Standard error of means of triplicate

Table 1. Proximate composition of raw and blanched leafy vegetables consumed in Southern Côte d'Ivoire

	Ash (%)	Fibres (%)	Proteins (%)	Lipids (%)	Carbohydrates (%)	Calorific value (kcal /100g)
C. esculenta						
Raw	15.03±0.23^{a}	24.00±0.46^{a}	9.80±0.16^{a}	8.35±0.15^{c}	42.85±2.68^{a}	252.34±1.55^{b}
15 min	9.96±0.06^{b}	24.15±0.07^{a}	8.81±0.02^{b}	9.80±0.08^{b}	35.79±1.93^{b}	255.63±2.58^{b}
25 min	9.93±0.04^{b}	24.28±0.46^{a}	8.57±0.00^{b}	10.00±0.02^{a}	35.36±0.08^{b}	260.05±0.85^{a}
45 min	8.75±1.38^{c}	24.58±0.40^{a}	8.13±0.00^{c}	10.20±0.25^{a}	36.36±0.86^{b}	264.28±4.88^{a}
B. alba						
Raw	19.79±0.44^{a}	16.50±0.30^{b}	9.86±0.10^{a}	6.85±0.05^{a}	47.00±0.89^{b}	249.18±2.41^{c}
15 min	13.10±0.14^{b}	17.45±0.21^{b}	9.38±0.00^{a}	3.81±0.00^{c}	54.27±0.35^{a}	253.34±0.18^{b}
25 min	12.95±0.04^{b}	17.83±0.04^{a}	8.75±0.00^{b}	3.99±0.13^{c}	49.49±0.35^{b}	248.49±0.18^{c}
45 min	12.86±0.12^{b}	18.09±0.01^{a}	8.50±0.02^{b}	4.49±0.00^{b}	54.07±0.13^{a}	256.18±0.40^{a}
S. melongena						
Raw	20.32±2.36^{a}	13.70±0.65^{c}	12.34±0.09^{a}	2.73±0.06^{d}	50.91±3.16^{a}	277.57±13.54^{a}
15 min	18.80±0.23^{b}	13.84±0.12^{c}	11.88±0.02^{a}	7.80±0.31^{a}	41.19±0.02^{b}	257.16±2.13^{b}
25 min	18.63±0.19^{b}	14.63±0.18^{b}	11.88±0.02^{a}	5.77±0.27^{c}	39.11±0.51^{c}	241.29±0.97^{c}
45 min	18.48±0.17^{b}	15.21±0.01^{a}	9.94±0.00^{b}	6.15±0.10^{b}	42.02±0.13^{b}	245.26±0.21^{c}
T. triangulare						
Raw	22.20±0.37^{a}	13.98±1.50^{c}	17.18±0.05^{a}	4.90±0.06^{c}	52.77±2.08^{a}	271.32±8.17^{a}
15 min	20.07±0.06^{b}	14.14±0.10^{c}	14.48±0.00^{b}	6.84±0.11^{b}	44.48±0.14^{b}	251.33±0.38^{b}
25 min	18.64±0.07^{c}	15.24±0.21^{b}	14.25±0.00^{b}	7.21±0.30^{a}	39.67±0.28^{c}	248.92±1.81^{b}
45 min	17.36±0.04^{d}	16.80±0.14^{a}	13.69±0.00^{c}	6.82±0.01^{b}	39.34±0.33^{c}	245.51±0.57^{c}
C. olitorius						
Raw	8.53±0.15^{a}	11.49±0.03^{c}	21.12±0.05^{a}	3.28±0.30^{a}	55.58±0.84^{b}	277.40±1.26^{a}
15 min	7.96±0.04^{b}	12.51±0.21^{b}	21.00±0.02^{a}	3.94±0.00^{a}	54.61±0.47^{b}	279.12±0.07^{a}
25 min	7.88±0.01^{b}	13.23±0.01^{a}	16.63±0.62^{b}	2.68±0.01^{b}	59.59±0.60^{a}	275.73±0.63^{a}
45 min	7.74±0.00^{c}	13.64±0.06^{a}	16.19±0.06^{b}	1.49±0.00^{c}	60.95±0.13^{a}	269.57±0.32^{b}

Data are represented as Means ± SD (n = 3). Means in the column with no common superscript differ significantly (P<0.05) for each leafy vegetable

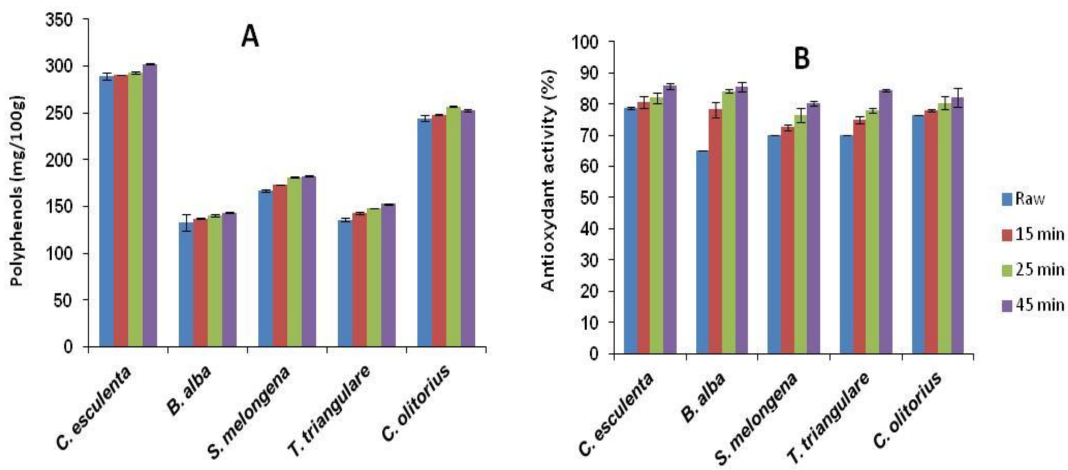

Fig. 3. Polyphenols contents (A) and antioxidant activity (B) of raw and blanched leafy vegetables consumed in Southern Côte d'Ivoire

Mean ± S.E.M = Mean values ± Standard error of means of triplicate

Table 2. Mineral composition of raw and blanched leafy vegetables consumed in Southern Côte d'Ivoire

	Ca	Mg	P	K	Fe	Na	Zn
C. esculenta							
Raw	587.24±0.55[a]	347.29±0.32[a]	788.00±0.74[a]	2281.63±2.14[a]	143.37±0.13[a]	39.45±0.16[a]	37.29±0.03[a]
15 min	214.71±1.21[b]	85.50±0.48[b]	263.85±1.12[b]	1769.41±10.04[b]	23.91±0.13[b]	32.28±0.18[b]	22.46±0.12[b]
25 min	196.49±0.83[c]	79.10±0.33[c]	244.73±1.38[c]	1743.32±7.44[b]	21.31±0.09[b]	27.94±4.43[c]	20.65±0.08[c]
45 min	185.96±9.48[c]	75.38±1.95[d]	238.47±7.81[c]	1522.63±24.44[c]	19.38±3.07[c]	25.96±0.02[c]	20.42±3.23[c]
B. alba							
Raw	750.34±0.53[a]	753.88±0.53[a]	390.14±0.27[a]	2709.43±1.93[a]	77.47±0.05[a]	555.01±5.99[a]	67.25±0.72[a]
15 min	442.82±1.20[b]	257.02±2.77[b]	332.87±0.90[b]	1243.32±13.42[b]	17.07±0.04[b]	520.21±1.42[b]	64.03±1.17[b]
25 min	430.09±4.64[c]	243.98±0.66[c]	297.55±3.21[c]	1149.65±3.13[c]	16.86±0.18[b]	466.38±5.00[c]	62.56±0.67[b]
45 min	395.65±4.24[d]	239.32±2.56[c]	286.59±2.83[d]	1034.62±11.10[d]	13.10±0.14[c]	350.63±0.25[d]	57.12±0.04[c]
S. melongena							
Raw	796.54±0.55[a]	481.90±0.33[a]	374.46±0.26[a]	2256.10±1.57[a]	139.48±0.09[a]	323.13±2.96[a]	64.64±0.04[a]
15 min	608.95±5.59[b]	185.54±2.23[b]	343.20±3.15[b]	2220.95±2.72[b]	45.86±0.42[b]	322.36±3.42[a]	34.66±1.31[b]
25 min	598.53±7.20[c]	181.63±1.66[b]	249.77±3.00[c]	1995.69±14.01[c]	42.10±0.44[b]	305.12±3.67[b]	32.63±0.39[b]
45 min	598.52±6.36[c]	172.63±1.83[c]	239.40±2.54[c]	1828.86±19.44[b]	36.04±0.43[c]	172.86±0.12[c]	30.77±0.32[c]
T. triangulare							
Raw	601.37±0.38[a]	755.97±0.48[a]	239.59±0.81[a]	5053.23±3.21[a]	102.28±0.06[a]	260.25±0.75[a]	36.10±0.02[a]
15 min	503.29±1.45[b]	435.00±1.48[b]	186.00±0.45[b]	2940.38±8.48[b]	23.25±4.34[b]	236.55±0.80[b]	29.24±0.09[b]
25 min	486.11±1.66[c]	433.81±1.25[b]	177.71±0.56[b]	2507.68±8.56[c]	21.86±0.07[b]	180.62±3.75[c]	26.70±0.07[c]
45 min	388.84±2.37[d]	358.51±6.00[c]	164.91±0.10[c]	1994.69±37.81[d]	19.88±0.05[c]	56.50±0.03[d]	21.93±4.09[d]
C. olitorius							
Raw	369.02±2.33[a]	234.51±0.38[a]	316.82±0.52[a]	2622.57±16.56[a]	97.60±0.16[a]	27.75±0.08[a]	24.71±0.04[a]
15 min	351.98±1.05[b]	143.34±0.90[b]	259.67±0.23[b]	2186.39±6.93[b]	36.92±0.11[b]	18.00±0.05[b]	17.48±0.05[b]
25 min	340.10±1.07[c]	141.90±0.45[b]	248.78±0.44[c]	1963.97±5.90[c]	32.17±0.20[c]	13.10±0.08[c]	16.59±0.04[c]
45 min	321.49±0.53[d]	136.22±0.40[c]	230.69±1.02[d]	1499.77±2.48[d]	32.16±0.10[c]	8.48±0.01[d]	15.09±0.09[d]

Data are represented as Means ± SD (n = 3). Means in the column with no common superscript differ significantly (P<0.05) for each leafy vegetable

Table 3. Anti-nutritional factors/mineral ratios of raw and blanched leafy vegetables consumed in Southern Côte d'Ivoire

	Phytate/Ca	Phytate/Fe	Oxalate/Ca
C. esculenta			
Raw	0.04±0.00^{b}	0.18±0.03^{b}	0.98±0.03^{c}
15 min	0.07±0.01^{a}	0.11±0.02^{c}	1.50±0.10^{b}
25 min	0.06±0.01^{a}	0.56±0.05^{a}	1.60±0.10^{a}
45 min	0.06±0.01^{a}	0.58±0.05^{a}	1.65±0.15^{a}
B. alba			
Raw	0.02±0.00^{b}	0.25±0.01^{d}	0.86±0.03^{c}
15 min	0.03±0.00^{a}	0.92±0.03^{a}	1.12±0.20^{a}
25 min	0.01±0.00^{b}	0.48±0.02^{c}	1.10±0.20^{a}
45 min	0.01±0.00^{b}	0.50±0.02^{b}	1.04±0.15^{b}
S. melongena			
Raw	0.05±0.00^{b}	0.29±0.01^{a}	0.11±0.01^{a}
15 min	0.01±0.00^{c}	0.17±0.01^{c}	0.12±0.01^{a}
25 min	0.13±0.02^{a}	0.19±0.01^{b}	0.08±0.01^{b}
45 min	0.01±0.00^{c}	0.19±0.01^{b}	0.06±0.01^{c}
T. triangulare			
Raw	0.04±0.00^{a}	0.28±0.01^{b}	0.80±0.01^{b}
15 min	0.01±0.00^{b}	0.35±0.01^{a}	1.01±0.30^{a}
25 min	0.01±0.00^{b}	0.21±0.01^{c}	0.11±0.01^{c}
45 min	0.01±0.00^{b}	0.21±0.01^{c}	1.10±0.10^{a}
C. olitorius			
Raw	0.10±0.02^{a}	0.39±0.02^{a}	2.11±0.50^{a}
15 min	0.03±0.00^{b}	0.36±0.02^{b}	1.48±0.20^{b}
25 min	0.03±0.00^{b}	0.34±0.01^{b}	1.45±0.20^{c}
45 min	0.02±0.00^{b}	0.28±0.01^{c}	1.41±0.30^{c}

Data are represented as Means± SD (n = 3). Means in the column with no common superscript differ significantly (P < 0.05) for each leafy vegetable

4. CONCLUSION

Fresh leafy vegetables used for sauce preparation in Southern Côte contain significant levels of nutrients such as minerals and vitamins which are important for maintaining the human body's health. In this work, blanching processing at 15, 25 and 45 minutes revealed a considerable decrease of the minerals, proteins, vitamin C, carotenoids and anti-nutritional factors (oxalates and phytates) contents. Even if blanching processing affects negatively the nutritive value of the selected leafy vegetables, it is important to highlight that the losses of anti-nutrients (oxalates, phytates) may have beneficial effect on the bioavailability of minerals such as magnesium, calcium, iron and zinc. In order to contribute efficiently to the nutritional requirement and to the food security of Ivorian population, the domestic blanching time must be less than 15 min for preserving the beneficial nutritive properties of leafy vegetables.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Vorster HJ, Jansen-Van-Rensburg WS, Venter SL, Van-Zijl JL. Recreating awareness of traditional leafy vegetables in communities. Regional workshop on African Leafy Vegetables for improved nutrition, IPGRI, Nairobi, Kenya; 2005.
2. Maundu P. The status of traditional vegetable utilization in Kenya. In Traditional African Vegetables. Guarino L. (Ed.), ICRAF-HQ, Nairobi, Kenya. IPGRI, Rome. 1997;66-71.
3. Mnzava NA. Vegetable crop diversification and the place of traditional species in the tropics. In: Proceedings of the IPGRI International workshop on genetic resources of traditional vegetables in Africa. Guarino L. (Ed.), ICRAF-HQ, Nairobi, Kenya. 1997;1-15.

4. Chadha ML. AVRDC's experiences within marketing of indigenous vegetables – A case study on commercialization of African eggplant AVRDC-Regional Center for Africa, Duluti, Arusha, Tanzania; 2003.
5. Gupta S, Lakshmi JA, Manjunath MN, Prakash J. Analysis of nutrient and antinutrient content of underutilized green leafy vegetables. LWT. 2005;38:339-45.
6. Norman JT, Kerri KG. Fruit, Vegetables, and the prevention of cancer: Research Challenges. Nutrition. 2003;19:467-70.
7. Lopez-Ayerra B, Murcia MA, Carmona GF. Lipid peroxidation and chlorophyll levels in Spinach during refrigerated storage and after industrial processing. Food Chem. 1998;61:113-8.
8. Barry IN, Germain NP, Hannah J, Detlef V. Production and marketing of African indigenous vegetables in Arumeru District of Tanzania: Assessing postharvest loss and processing potential. International symposium "Underutilized plants for food, nutrition, income and sustainable development". Arusha, Tanzania; 2008.
9. Chweya JA. Identification and nutritional importance of indigenous green leafy vegetables in Kenya. Acta Hort. 1985;153:99-108.
10. Soetan KO, Oyewole OE. The need for adequate processing to reduce the anti-nutritional factors in plants used as human foods and animal feeds: A review. Afr J Food Sci. 2009;9:223-32.
11. Gupta S, Jyothi LA, Prakash J. Effect of different blanching treatments on ascorbic acid retention in green leafy vegetables. Natural Prod Rad. 2008;7:111-6.
12. Pilnik W, Voragen AG. The significance of endogenous and exogenous enzymes in fruit and vegetable processing. In: Food Enzymology, P.F. Fox (Ed.), Barking, Elsevier. 1991;254–301.
13. Barrett DM, Theerakulkait C. Quality indicators in blanched, frozen vegetables. Food Technol. 1995;49:62–5.
14. Prestamo G, Fuster C, Risueno MC. Effects of blanching and freezing on the structure of carrots cells and their implications for food processing. J Sci Food Agric. 1998;77:223–9.
15. Murcia MA, Lopez-Ayerra B, Garcia-Carmona F. Effect of processing methods and different blanching times on broccoli: proximate composition and fatty acids. Leben Wiss Technol. 1999;32:238–43.
16. Oboh G. Effect of blanching on the antioxidant properties of some tropical green leafy vegetables. Leben Wiss Technol. 2005;38:513–7.
17. PROTA. Ressources végétales de l'Afrique tropicale. Volume 2 : Légumes. Grubben GJH. et Denton OA. (eds). Fondation PROTA / Backhuys Publishers / CTA, Wageningen; 2004.
18. Fondio L, Kouamé C, N'zi JC, Mahyao A, Agbo E, Djidji AH. Survey of indigenous leafy vegetable in the urban and peri-urban areas of Côte d'Ivoire. Acta Hort. 2007;752:287-9.
19. Soro LC, Atchibri LO, Kouadio KK, Kouamé C. Evaluation de la composition nutritionnelle des légumes-feuilles. J Appl Biosci. 2012;51:3567–73. French.
20. Acho FC, Zoué LT, Akpa EE, Yapo VG, Niamké SL. Leafy vegetables consumed in Southern Côte d'Ivoire: a source of high value nutrients. J Anim Plant Sci. 2014;20:3159-70.
21. Oulai PD, Zoué LT MA, Bedikou ME, Megnanou RM, Niamké SL. Impact of cooking on nutritive and antioxidant characteristics of leafy vegetables consumed in Northern Côte d'Ivoire. Int J Plant Anim Env Sci. 2014;4:576-85.
22. Zoro AF, Zoué LT MA, Bedikou ME, Kra SA, Niamké SL. Effect of cooking on nutritive and antioxidant characteristics of leafy vegetables consumed in Western Côte d'Ivoire. Arch Appl Sci Res. 2014; 6:114-23.
23. AOAC. Official methods of analysis. Association of Official Analytical Chemists Ed., Washington DC; 1990.
24. FAO. Food energy-methods of analysis and conversion factors. FAO Ed, Rome ; 2002.
25. CEAEQ, Détermination des métaux. Méthode par spectrométrie de masse à source ionisante au plasma d'argon. MA 200 – Met 1.2, Rev 4. Quebec; 2013.
26. Day RA, Underwood AL. Quantitative analysis. 5th ed. Prentice Hall; 1986.
27. Latta M, Eskin M. A simple method for phytate determination. J Agric Food Chem. 1980;28:1313-5.
28. Pongracz G, Weiser H, Matzinger D. Tocopherols- Antioxydant. Fat Sci Technol. 1971;97:90-104.
29. Rodriguez-Amaya DB. A guide to carotenoids analysis in foods. ILSI Press, Washington DC; 2001.

30. Singleton VL, Orthofer R, Lamuela-Raventos RM. Analysis of total phenols and other oxydant substrates and antioxydants by means of Folin-ciocalteu reagent. Methods Enzymol. 1999; 299:152-78.
31. Choi CW, Kim SC, Hwang SS, Choi BK, Ahn HJ, Lee MZ, Park SH, Kim SK. Antioxydant activity and free radical scavenging capacity between Korean medicinal plant and flavonoids by assay guided comparison. Plant Sci. 2002;163: 1161-8.
32. Antia BS, Akpan EJ, Okon PA, Umoren IU. Nutritive and anti-nutritive evaluation of sweet potato (*Ipomea batatas*) leaves. Pak J Nutr. 2006;5:166-8.
33. Lund DB. Effects of heat processing on nutrients. In: Nutritional Evaluation of Food Processing, (R. Harries and E. Karmas, eds). The AVI Publishing Co. Inc Westport; 1997.
34. Lola A. The effect of boiling on the nutrients and anti-nutrients in two non conventional vegetables. Pak J Nutr. 2009; 8:1430-3.
35. Ali A. Proximate and mineral composition of the marchubeh (*Asparagus officinalis*). World Dairy Food Sci. 2009;4:142-9.
36. Svanberg SM, Nyman EM, Andersson L, Nilsson R. Effects of boiling and storage on dietary fiber and digestible carbohydrates in various cultivars of carrots. J Sci Food Agric. 1997;73:245–54.
37. Ishida H, Suzuno H, Sugiyama N, Innami S, Todokoro T, Maekawa A. Nutritional evaluation of chemical component of leaves stalks and stems of sweet potatoes (*Ipomea batatas*). Food Chem. 2000; 68:359-67.
38. Ejoh AR, Tchouanguep MF, Fokou E. Nutrient composition of the leaves and flowers of *Colocasia esculenta* and the fruits of *Solanum melongena*. Plant Food Hum Nutr. 1996;49:107-12.
39. Sobowale SS, Olatidoye OP, Olorode OO, Akinlotan JV. Nutritional potentials and chemical value of some tropical leafy vegetables consumed in south west Nigeria. J Sci Multi Res. 2011;3:55-65.
40. FAO. Human vitamin and mineral requirements. FAO Ed; 2004.
41. Turan M, Kordali S, Zengin H, Dursun A, Sezen Y. Macro and micro-mineral content of some wild edible leaves consumed in Eastern Anatolia. Plant Soil Sci. 2003;53: 129-37.
42. Chaturvedi VC, Shrivastava R, Upreti RK. Viral infections and trace elements: A complex trace element. Curr Sci. 2004; 87:1536-54.
43. Trowbridge F, Martorell M. Forging effective strategies to combat iron deficiency. J Nutr. 2002;85:875-80.
44. Hassan LG, Umar KJ, Umar Z. Anti-nutritive factors in *Tribulus terrestris* (Linn) leaves and predicted calcium and zinc bioavailability. J Trop Biosci. 2007;7:33-6.
45. Umar KJ, Hassan LG, Dangoggo SM, Inuwa M, Amustapha MN. Nutritional content of *Melochia corchorifolia* (Linn.) leaves. Int J Biol Chem Sci. 2007;1:250-5.
46. Weenanan S, Ratchanee K, Pongtorn S, Rin C. Effects of three conventional cooking methods on vitamin C, tannin, myo-inositol phosphates contents in selected Thai vegetables. J Food Comp Anal. 2008;21:187 –97.
47. Sandberg AS. Bioavailability of minerals in legumes. Brit J.Nutr. 2002;88:281-5.
48. Ekop AS, Eddy NO, Comparative Studies of the level of toxicants in the seed of Indian almond (*Terminalia catappa*) and African walnut (*Coula edulis*). Chem Class J. 2005;2:74-6.
49. Speek AJ, Temalilwa GR, Schrijver J. Determination of β-carotene content and vitamin A activity of vegetables by HPLC. Food Chem. 1986;19:65-74.
50. Rodriguez-Amaya DB. A guide to carotenoids analysis in foods. ILSI Press, Washington DC; 2001.
51. Takyi EE. Children's consumption of dark green leafy vegetables with added fat enhances serum retinol. J Nutr. 1999;129:1549-54.
52. Gupta S, Jyothi LA, Prakash J. Effect of different blanching treatments on ascorbic acid retention in green leafy vegetables. Nat Prod Rad. 2008;7:111-6.
53. Yamaguchi T, Mizobuchi T, Kajinawa H, Miyabe F, Terao J, Takamura H, Matoba T. Radical-scavenging activity of vegetables and the effect of cooking on their activity. Food Sci Technol Res; 2001;7:250–7.
54. Oboh G, Rocha JB. Polyphenols in red pepper and their protective effect on some pro-oxidants induced lipid peroxidation in brain and liver. Eur Food Res Technol. 2007;225:239-47.
55. Dewanto V, Wu X, Adom KK, Liu RH. Thermal processing enhances the nutritional value of tomatoes by increasing

total anti- oxidant activity. J Agric Food Chem. 2002;50:3010-4.
56. Rice-Evans C, Miller NJ. Antioxidants: the case for fruit and vegetables in the diet. Brit Food J. 1995;97:35-40.
57. Amic D, Davidovic-Amic D, Beslo D, Trinajstic N. Structure-radical scavenging activity relationship of flavonoids. Croatia Chem Acta. 2003;76:55-61.

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